

# Notice of Allowability

Application No.

09/730,681

Examiner

Qutub Ghulamali

Applicant(s)

GREEN ET AL.

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-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTOL-85) or other appropriate communication will be mailed in due course. **THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS.** This application is subject to withdrawal from issue at the initiative of the Office or upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1. ☒ This communication is responsive to amendment filed 12/23/2005.
2. ☒ The allowed claim(s) is/are 1-27, 50, 70-80 which are now renumbered as claims 1-27, 28, 31, 32, 35, 38, 29, 30, 33, 34, 36, 37, 39 respectively.
3. ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).
  - a) ☐ All   b) ☐ Some\*   c) ☐ None   of the:
    1. ☐ Certified copies of the priority documents have been received.
    2. ☐ Certified copies of the priority documents have been received in Application No. \_\_\_\_\_.
    3. ☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

\* Certified copies not received: \_\_\_\_\_.

Applicant has THREE MONTHS FROM THE "MAILING DATE" of this communication to file a reply complying with the requirements noted below. Failure to timely comply will result in ABANDONMENT of this application.  
**THIS THREE-MONTH PERIOD IS NOT EXTENDABLE.**

4. ☐ A SUBSTITUTE OATH OR DECLARATION must be submitted. Note the attached EXAMINER'S AMENDMENT or NOTICE OF INFORMAL PATENT APPLICATION (PTO-152) which gives reason(s) why the oath or declaration is deficient.
5. ☒ CORRECTED DRAWINGS ( as "replacement sheets") must be submitted.
  - (a) ☐ including changes required by the Notice of Draftsperson's Patent Drawing Review ( PTO-948) attached
    - 1) ☐ hereto or 2) ☐ to Paper No./Mail Date \_\_\_\_\_.
  - (b) ☒ including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No./Mail Date \_\_\_\_\_.Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the front (not the back) of each sheet. Replacement sheet(s) should be labeled as such in the header according to 37 CFR 1.121(d).
6. ☐ DEPOSIT OF and/or INFORMATION about the deposit of BIOLOGICAL MATERIAL must be submitted. Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

## Attachment(s)

1. ☒ Notice of References Cited (PTO-892)
2. ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)
3. ☐ Information Disclosure Statements (PTO-1449 or PTO/SB/08), Paper No./Mail Date \_\_\_\_\_
4. ☐ Examiner's Comment Regarding Requirement for Deposit of Biological Material
5. ☐ Notice of Informal Patent Application (PTO-152)
6. ☒ Interview Summary (PTO-413), Paper No./Mail Date \_\_\_\_\_
7. ☒ Examiner's Amendment/Comment
8. ☒ Examiner's Statement of Reasons for Allowance
9. ☐ Other \_\_\_\_\_

## **DETAILED ACTION**

### ***Response to Amendment***

1. Applicant's after-final amendment/remarks filed 12/23/2005 have been fully considered and as a result claims 1-27, 50, 70-80 are now indicated allowable. However, an examiners amendment was considered necessary in order to place the application in a proper condition for allowance.

### **EXAMINER'S AMENDMENT**

2. An examiner's amendment to the record appears below. Should the changes and/or additions be unacceptable to applicant, an amendment may be filed as provided by 37 CFR 1.312. To ensure consideration of such an amendment, it MUST be submitted no later than the payment of the issue fee.

Authorization for this examiner's amendment was given in a telephone interview with Mr. Edwin Suominen on 1/13/2006.

3. The application has been amended as follows:

IN THE CLAIMS:

-- **Claim 1** (currently amended) A method for determining vector mismatch between a plurality of signal paths in a signal processing system, the method comprising:

(a) providing a periodic calibration signal having a plurality of tones;

- (b) frequency translating the calibration signal using the signal processing system to provide a ~~first~~ set of observed samples;
- (c) comparing the ~~first-sample~~ set of observed samples to a ~~second~~ set of samples modeled by a function of parameters including an estimated vector mismatch and a plurality of basis functions; and
- (d) determining, at least to an estimate, a value of vector mismatch that minimizes the difference between the ~~first-sample~~ set of observed samples and the ~~second-sample~~ set of modeled samples.

**Claim 2 (original)** The method of claim 1 wherein:

- (a) the signal paths include an in-phase signal path and a quadrature signal path; and
- (b) vector mismatch includes deviation from a quadrature relationship between the in-phase signal path and the quadrature signal path.

**Claim 3 (original)** The method of claim 1 wherein:

- (a) the signal paths include a plurality of signal paths coupled to respective elements of a spatially selective array; and
- (b) vector mismatch includes deviations from a predetermined phase and amplitude relationship between each respective one of the plurality of signal paths, the deviations degrading spatial selectivity of the array.

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**Claim 4** (original) The method of claim 3 further comprising transmitting the calibration signal through an antenna placed at a fixed position with respect to the array elements.

**Claim 5** (currently amended) The method of claim 1 wherein the number of samples in the sample set of modeled samples is significantly greater than the number of parameters of the function, whereby the function is over determined.

**Claim 6** (currently amended) The method of claim 1 further comprising:

- (a) providing a plurality of ~~first sample~~ sets of observed samples;
- (b) comparing each ~~first sample~~ set of observed samples to a respective ~~second sample~~ set of samples modeled as [a] said function of parameters ~~including an estimated vector mismatch, and a plurality of basis functions~~;
- (c) determining, at least to an estimate, a value of vector mismatch that minimizes the difference between each ~~first sample~~ set of observed samples and each respective ~~second sample~~ set of modeled samples; and
- (d) statistically combining the values of vector mismatch determined for each one of the plurality of ~~first sample~~ sets of observed samples.

**Claim 7** (original) The method of claim 1 wherein the determined vector mismatch includes a first value representative of phase mismatch and a second value representative of gain mismatch, the values being representative of mismatches between the signal paths.

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**Claim 8** (currently amended) The method of claim 7 wherein:

- (a) the determined vector mismatch includes a plurality of phase and gain mismatch values;
- (b) the plurality of phase and gain mismatch values includes a phase and gain mismatch value for each one of the plurality of tones; and
- (c) each one of the plurality of phase and gain mismatch values is representative of vector mismatch between the signal paths from frequency translation of one of the plurality of tones.

**Claim 9** (original) The method of claim 1 wherein the parameters further include a parameter indicative of at least one environmental condition.

**Claim 10** (original) The method of claim 9 wherein the environmental condition is a temperature.

**Claim 11** (original) The method of claim 9 wherein the environmental condition is a local oscillator frequency.

**Claim 12** (original) The method of claim 1 wherein each one of the plurality of basis functions forms an orthogonal basis for each one of the plurality of tones.

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**Claim 13** (original) The method of claim 1 wherein:

(a) the plurality of basis functions includes a first function set and a second function set; and

(b) one basis function of the first function set and one basis function of the second function set together form an orthogonal basis for each one of the plurality of tones.

**Claim 14** (original) The method of claim 13 wherein:

(a) each one of the plurality of basis functions is sinusoidal and periodic at a frequency equal to the frequency of the tone whose orthogonal basis is formed thereby; and

(b) each basis function of the first function set is displaced from each basis function of the second function set by a predetermined phase offset to establish a predetermined vector relationship there between.

**Claim 15** (currently amended) The method of claim 1 wherein the value of vector mismatch that minimizes the difference between the ~~first sample set~~ of observed samples and the ~~second sample set~~ of modeled samples is determined by recursive least mean squares.

**Claim 16** (original) The method of claim 15 wherein the values determined by least mean squares are constrained to a predetermined bounded region.

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**Claim 17** (currently amended) The method of claim 1 wherein the value of vector mismatch that minimizes the difference between the ~~first sample~~ set of observed samples and the ~~second sample~~ set of modeled samples is determined by recursive least squares with an exponential forgetting window.

**Claim 18** (currently amended) The method of claim 1 wherein:

(a) the function is a linear product of

(1) a matrix of results of the basis functions; and

(2) a parameter vector of variables representative of the vector mismatch; and

(b) the value of vector mismatch that minimizes the difference between the ~~first sample~~ set of observed samples and the ~~second sample~~ set of modeled samples is determined by linear regression estimation of the parameter vector.

**Claim 19** (currently amended) The method of claim 18 wherein X is the matrix, Y is the observation vector, Z is the parameter vector, and the linear regression estimation is determined according to the formula:

$$Z = (X^T X)^{-1} X^T Y$$

**Claim 20** (currently amended) A method in accordance with claim 1 for reducing vector mismatch between signal paths in [a] the signal processing system, the method further

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comprising applying at least one of a phase adjustment and a gain adjustment to at least one of the signal paths.

**Claim 21** (original) The method of claim 20 further comprising:

- (a) computing complex exponentials corresponding to the vector mismatch; and
- (b) based on the complex exponentials, deriving coefficients of impulse response that is inversely representative of the vector mismatch; and
- (c) realizing the impulse response in a digital filter to apply the adjustment.

**Claim 22** (original) The method of claim 21 wherein the coefficients are derived by applying the complex exponentials to appropriate frequency bands of an inverse fast Fourier transform.

**Claim 23** (original) The method of claim 21 wherein the digital filter is a finite-impulse-response filter.

**Claim 24** (original) The method of claim 20 further comprising repeatedly determining vector mismatch and applying a phase and gain adjustment, inverse of the determined vector mismatch, to reduce the vector mismatch.



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**Claim 25** (currently amended) A signal processing system having an in-phase signal path and a quadrature signal path and including a vector mismatch determination system comprising:

- (a) a calibration signal subsystem that, during operation, provides a periodic calibration signal having a plurality of tones;
- (b) a sample modeling and mismatch determination subsystem responsive to the calibration signal to provide a plurality of ~~first~~ sets of observed samples and determine vector mismatch between the plurality of signal paths, vector mismatch including deviation from a quadrature relationship between the in-phase signal path and the quadrature signal path, wherein, during operation:
  - (1) each ~~first sample~~ set of observed samples is compared to a respective ~~second~~ set of samples modeled by a linear product of a parameter vector of variables representative of an estimated vector mismatch and a matrix of results from a plurality of basis functions, the estimated vector mismatch including a plurality of values representative of phase mismatch and a plurality of values representative of gain mismatch at each one of the plurality of tones;
  - (2) a value of vector mismatch is determined, at least to an estimate, that minimizes the difference between ~~the first sample~~ each set of observed

samples and the ~~second sample~~ respective set of modeled samples, the determination being made by a bounded least mean squares algorithm;

(3) the number of samples in the ~~sample~~ set of modeled samples is significantly greater than the number of parameters of the function, whereby the function is over determined;

(4) the values of vector mismatch determined for each one of the plurality of ~~first sample~~ sets of observed samples are statistically combined;

(5) the plurality of basis functions includes a first function set and a second function set, one basis function of the first function set and one basis function of the second function set together forming an orthogonal basis for each one of the plurality of tones;

(6) each one of the plurality of basis functions is sinusoidal and periodic at a frequency equal to the frequency of the tone whose orthogonal basis is formed thereby; and

(7) each basis function of the first function set is displaced from each basis function of the second function set by a predetermined phase offset to establish a predetermined vector relationship there between.

**Claim 26** (currently amended) A system in accordance with claim 25 for reducing vector mismatch between quadrature signal paths in [a] the signal processing system, wherein, during operation at least one of a phase adjustment and a gain adjustment is

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repeatedly determined and applied to at least one of the signal paths, the system further comprising:

- (a) a correction coefficient generator responsive to the determined value of vector mismatch to compute complex exponentials corresponding to the vector mismatch;
- (b) a coefficient generator responsive to the complex exponentials to derive coefficients of an impulse response that is inversely representative of the vector mismatch, the coefficients being derived by applying the complex exponentials to appropriate frequency bands of an inverse fast Fourier transform; and
- (c) a finite-impulse-response digital filter coupled to the coefficient generator to realize the impulse response and apply the adjustment.

**Claim 27** (currently amended) A signal processing system comprising:

- (a) means for providing a periodic calibration signal having a plurality of tones;
- (b) means for frequency translating the calibration signal to provide a ~~first~~ set of observed samples;
- (c) means for comparing the ~~first sample set~~ of observed samples to a ~~second~~ set of samples modeled by a function of parameters including an estimated vector mismatch and a plurality of basis functions; and

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(d) means for determining, at least to an estimate, a value of vector mismatch that minimizes the difference between the ~~first-sample~~ set observed samples and the ~~second-sample~~ set of modeled samples.

Claims 28-49 (canceled).

Claim 50 (currently amended) A method for determining vector mismatch between a plurality of signal paths in a signal processing system that includes a digital signal processor, the method comprising:

- (a) providing a periodic calibration signal;
- (b) frequency translating the calibration signal using the signal processing system to provide a plurality of ~~first~~ sets of observed samples;
- (c) when processing time of the digital signal processor is available, performing a vector mismatch calibration process based on one of the ~~first-sample~~ sets of observed samples, the process including:
  - (1) comparing the ~~first-sample~~ each set of observed samples to a respective ~~second-sample~~ set of samples modeled as a function of parameters including an estimated vector mismatch and a plurality of basis functions; and

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- (2) determining, at least to an estimate, a value of vector mismatch that minimizes the difference between each ~~first-sample~~ set of observed samples and each respective ~~second-sample~~ set of modeled samples; and
- (d) statistically combining the values of vector mismatch determined for each one of the plurality of ~~first-sample~~ sets of observed samples.

Claim 51-69 (canceled).

Claim 70 (currently amended) Apparatus for determining vector mismatch between a plurality of signal paths in a signal processing system that includes a digital signal processor, the apparatus comprising:

- (a) means for providing a periodic calibration signal;
- (b) means for frequency translating the calibration signal to provide a plurality of ~~first~~ sets of observed samples;
- (c) means for determining when processing time of the digital signal processor is available and, during available processing time, performing a vector mismatch calibration process based on one of the ~~first-sample~~ sets of observed samples, the process including:
  - (1) comparing the ~~first-sample~~ set of observed samples to a respective ~~second-sample~~ set of samples modeled as a function of parameters

including an estimated vector mismatch and a plurality of basis

functions; and

(2) determining, at least to an estimate, a value of vector mismatch that minimizes the difference between each ~~first-sample~~ set of observed samples and each respective ~~second-sample~~ set of modeled samples; and

(d) means for statistically combining the values of vector mismatch determined for each one of the plurality of ~~first-sample~~ sets of observed samples.

**Claim 71** (currently amended) A signal processing system having an in-phase signal path and a quadrature signal path and including a vector mismatch determination system comprising:

(a) a calibration signal subsystem that, during operation, provides a periodic calibration signal having a plurality of tones; and

(b) a sample modeling and mismatch determination subsystem responsive to the calibration signal to provide a plurality of ~~first~~ sets of observed samples and determine vector mismatch between the plurality of signal paths, vector mismatch including deviation from a quadrature relationship between the in-phase signal path and the quadrature signal path, wherein, during operation:

(1) each ~~first-sample~~ set of observed samples is compared to a respective ~~second~~ set of samples modeled by a function of parameters including an estimated vector mismatch and a plurality of basis functions; and

(2) a value of vector mismatch is determined, at least to an estimate, that minimizes the difference between ~~the first sample~~ each set of observed samples and the ~~second sample~~ respective set of modeled samples.

**Claim 72** (currently amended) Apparatus for determining vector mismatch between a plurality of signal paths in a signal processing system that includes a digital signal processor, the apparatus comprising:

(a) means for providing a periodic calibration signal;

(b) means for frequency translating the calibration signal to provide a plurality of ~~first~~ sets of observed samples;

(c) means for determining when processing time of the digital signal processor is available and, during available processing time, performing a vector mismatch calibration process based on one of the ~~first sample sets~~ of observed samples, the process including:

(1) comparing ~~the first sample~~ each set of observed samples to a respective ~~second sample~~ set of samples modeled as a function of parameters including an estimated vector mismatch and a plurality of basis functions; and

(2) determining, at least to an estimate, a value of vector mismatch that minimizes the difference between each ~~first sample~~ set of

observed samples and each respective ~~second-sample~~ set of modeled samples; and

(d) means for statistically combining the values of vector mismatch determined for each one of the plurality of ~~first-sample~~ sets of observed samples.

**Claim 73** (currently amended) A signal processing system having an in-phase signal path and a quadrature signal path and including a vector mismatch determination system comprising:

(a) a calibration signal subsystem that, during operation, provides a periodic calibration signal having a plurality of tones; and

(b) a sample modeling and mismatch determination subsystem including a digital signal processor and responsive to a determination of when processing time of the digital signal processor is available, wherein, during operation:

(1) during available processing time, the sample modeling and mismatch determination subsystem is responsive to the calibration signal to provide a plurality of ~~first~~ sets of observed samples and determine vector mismatch between the plurality of signal paths, vector mismatch including deviation from a quadrature relationship between the in-phase signal path and the quadrature signal path;



(2) each ~~first sample~~ set of observed samples is compared to a respective ~~second~~ set of samples modeled by a function of parameters including an estimated vector mismatch and a plurality of basis functions; and

(3) a value of vector mismatch is determined, at least to an estimate, that minimizes the difference between ~~the first sample~~ each set of observed samples and the ~~second sample~~ set of modeled samples.

**Claim 74** (previously presented) The method of claim 50 wherein the determined vector mismatch includes a first value representative of phase mismatch and a second value representative of gain mismatch, the values being representative of mismatches between the signal paths.

**Claim 75** (currently amended) The method of claim 74 wherein:

(a) the determined vector mismatch includes a plurality of phase and gain mismatch values;

(b) the periodic calibration signal has a plurality of tones;

(c) the plurality of values includes a phase and gain mismatch value for each one of the plurality of tones; and

(~~e~~) (d) each one of the plurality of values is representative of vector mismatch between the signal paths from frequency translation of one of the plurality of tones.

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**Claim 76** (currently amended) The system of claim 71 wherein the vector mismatch determined by the sample modeling and mismatch determination subsystem responsive to the calibration signal includes: (a) a first value representative of phase mismatch between the in-phase and quadrature signal paths and (b) a second value representative of gain mismatch between the in-phase and quadrature signal paths.

**Claim 77** (currently amended) The system of claim 76 wherein:

- (a) the determined vector mismatch includes a plurality of phase and gain mismatch values;
- (b) the plurality of values includes a phase and gain mismatch value for each one of the plurality of tones of the periodic calibration signal; and
- (c) each one of the plurality of values is representative of vector mismatch between the in-phase and quadrature signal paths from frequency translation of one of the plurality of tones.

**Claim 78** (currently amended) The apparatus of claim 72 wherein the vector calibration process performed by the means of part (c) includes determining, at least to an estimate, a value of vector mismatch that includes a first value representative of phase mismatch and a second value representative of gain mismatch, the ~~values~~ first value and the second value being representative of mismatches between the signal paths.

**Claim 79** (currently amended) The apparatus of claim 78 wherein:

- (a) the determined vector mismatch includes a plurality of phase and gain mismatch values;
- (b) the periodic calibration signal has a plurality of tones;
- (c) the plurality of values includes a phase and gain mismatch value for each one of the plurality of tones; and
- (e) (d) each one of the plurality of values is representative of vector mismatch between the signal paths from frequency translation of one of the plurality of tones.

**Claim 80** (currently amended) The system of claim 73 wherein the vector mismatch determined by the sample modeling and mismatch determination subsystem responsive to the calibration signal includes a plurality of deviations from a quadrature relationship between the in-phase and quadrature signal paths, one for each one of the plurality of tones of the calibration signal. --

***Reasons for Allowance***

- 4. As indicated by applicant in remarks filed December 23, 2005 (see pages 21-26), claims 1-27, 50, 70-73 are now indicated allowable along with newly added claims 74-80 (reciting substantially similar limitations).
- 5. Claims 1-27, 50, 70-80 allowed.

Any comments considered necessary by applicant must be submitted no later than the payment of the issue fee and, to avoid processing delays, should preferably accompany the issue

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fee. Such submissions should be clearly labeled "Comments on Statement of Reasons for Allowance."

*Contact Information*

6. Any inquiry concerning this communication or earlier communications from the examiner should be directed to Qutub Ghulamali whose telephone number is (571) 272-3014. The examiner can normally be reached on Monday-Friday from 8:00AM - 5:00PM.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Jay Patel can be reached on (571) 272-2988. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see <http://pair-direct.uspto.gov>. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free).

QG.  
January 13, 2006.

  
JEAN B. CORRIELUS  
PRIMARY EXAMINER

1-20-06